SOIL PHYSICS
LABORATORY MANUAL

MOSIER AND GUSTAFSON
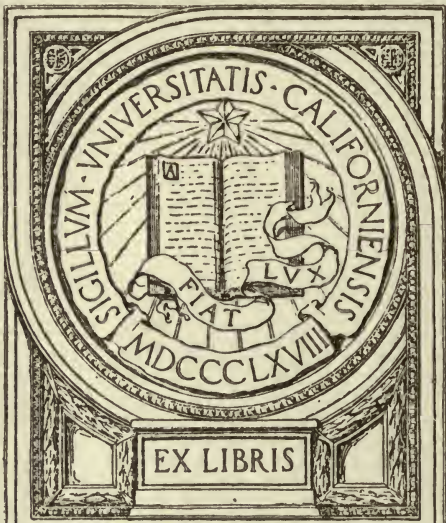
SOIL PHYSICS
LABORATORY MANUAL

BY

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PREFACE

These practices are the result of ten years' experience in teaching soil physics, and are designed for one semester's work, during which it is hoped to give the student a knowledge of the principles that underlie many common agricultural operations.

In a number of practices students may work together in groups, not so large, however, but that each one may have a distinct problem to work out in each practice. This plan will enable the class to complete the work in one semester, which otherwise might not be possible.

Questions are asked and references given to enable the student to get the greatest amount of information possible out of each practice.

An appendix of additional practices is added for students who wish to pursue the subject further.

<div align="right">THE AUTHORS</div>

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CONTENTS

APPARATUS FOR EACH STUDENT

1 Asbestos mat, 10 cm. square
4 Beakers, assorted sizes
1 Blue pencil, wax for marking on glass
1 Brush, camel's-hair
1 Bunsen burner
1 Capsule, horn, 10 cm. long
1 Cheesecloth, one yard
4 Corks, same size as No. 8 rubber stopper
6 Crucibles, 25 cc.
6 Crucibles, 50 cc.
1 Desiccator, 15 cm. in diameter
4 Erlenmeyer flasks, 250 to 500 cc.
1 Forceps, brass, 10 cm. long
4 Funnels, 10 cm. in diameter
1 Graduated cylinder, 100 cc.
1 Box of gummed labels
6 Jars, Mason's pint
1 Vial of litmus paper, blue
1 Box of matches
1 Mortar and pestle, 12.5 cm. in diameter

1 Ring stand, small, medium, and large rings
1 Rubber policeman on glass rod 20–22 cm. long
4 Rubber stoppers, No. 8
1 Ruler, 30 cm., 12 inch
4 Shaker bottles, 375 to 400 cc.
12 Soil pans, 10 cm. square, 5 cm. deep
2 Soil pans, 10 × 22 cm., 5 cm. deep
1 Spatula, 15 cm. blade
1 Spoon, horn, 10 cm. long
2 Test tubes
1 Tongs, crucible, 20 to 25 cm. long
2 Towels
1 Triangle, pipestem flanged, medium
1 Wash bottle, 500 to 750 cc.
5 Watch glasses 56 mm., $2\frac{1}{4}$ inches in diameter
4 Watch glasses 106 mm., $4\frac{1}{4}$ inches in diameter
8 Weighing bottles, 30 mm. in height and diameter

WEIGHTS AND MEASURES

1 Meter = 39.37 inches = 3.28 feet
1 Centimeter = .3937 inches
1 Kilogram = 2.2 pounds avoirdupois
1 Liter = $\begin{cases} 1.056 \text{ quarts} \\ 61.02 \text{ cubic inches} \end{cases}$
1 Inch = $\begin{cases} 25.399 \text{ millimeters} \\ 2.5399 \text{ centimeters} \end{cases}$
1 Pound = 453.59 grams
1 Cubic foot of water weighs 62.42 pounds
1 Square foot inch of water weighs 5.201 pounds
1 Acre inch of water = 226,000 pounds (approximately)
1 Acre = 43,560 square feet
Circumference of a circle = $2 \pi r$ or πD
Area of circle = πr^2
Area of a sphere = $4 \pi r^2$ or πD^2
Volume of a sphere = $\frac{4}{3}\pi r^3$ or $\frac{1}{6}\pi D^3$
Volume of a cylinder = $\pi r^2 h$; $h=$ altitude

SOIL PHYSICS
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STOCK SOILS AND THEIR PREPARATION

The soils commonly used are (1) a sand or sandy loam, (2) a gray silt or gray silt loam, (3) a brown silt loam, (4) a clay or clay loam, and (5) peat. Any other soils may be used. The selection of soils for class use should depend largely on the locality. The prevailing types in the vicinity should be used.

These soils should be thoroughly air-dried, and ground sufficiently fine to pass through a 2-mm. sieve.

COLLECTING SOIL SAMPLES

In collecting samples of soil a one and one-half or a two-inch auger with an extension, making it 40 inches long, should be used. Select the place for sampling and remove any vegetation. Collect the surface soil to a depth of approximately $6\frac{2}{3}$ inches, or to the plow line. Enlarge the hole by reaming out with the auger so that the subsurface soil may be removed without coming in contact with the surface soil. Take the subsurface sample to the depth of 20 inches. This gives the subsurface $13\frac{1}{3}$ inches, or twice that of the surface. It may be desirable in some cases to take the subsurface to the natural subsoil line, as indicated by the change in color and physical composition, usually from 15 to 20 inches in depth. Enlarge and clean out the hole as before and collect the subsoil to a depth of 40 inches. It may be convenient to divide the subsoil into two equal parts of 10 inches each. In collecting samples for moisture determinations, expose the soil to the air as little as possible before putting in jars.
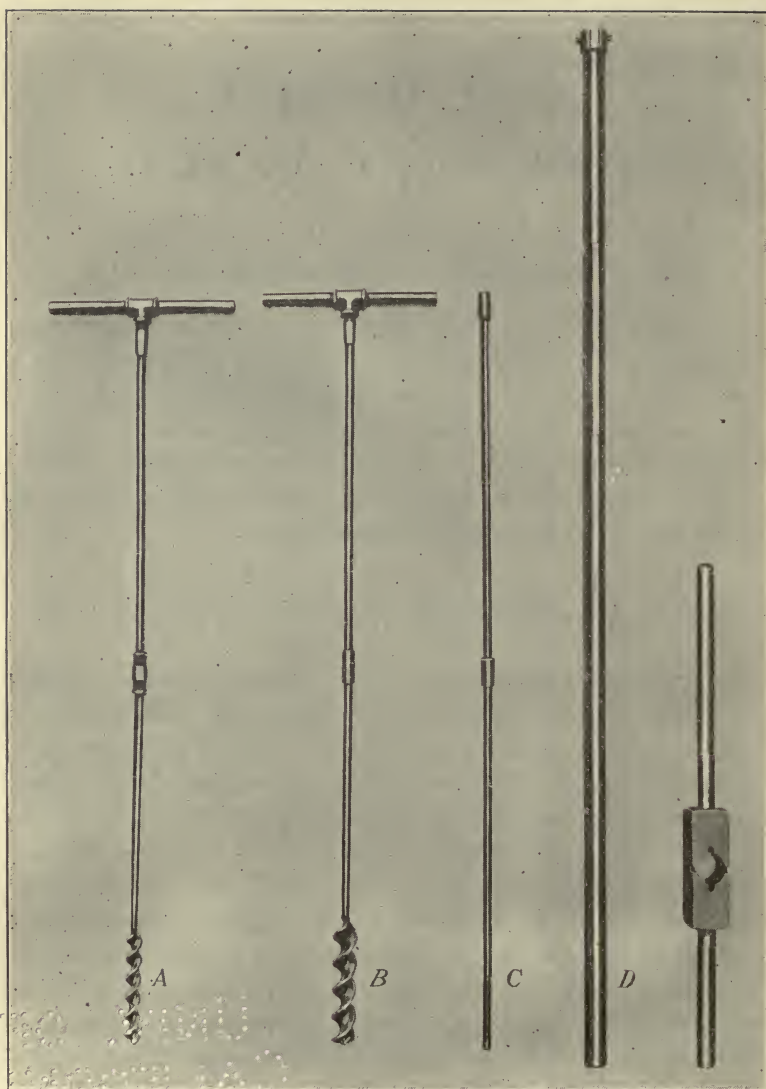
Fig. 1. Soil Samplers

A, one-inch field auger; *B*, one and one-half to two-inch sampling auger; *C*, extension rods; *D*, King's soil-sampling tube; *E*, hammer for forcing *D* into soil.

PRACTICE I

DETERMINATION OF CAPILLARY MOISTURE IN SOILS

The moisture content in these exercises will always be expressed as per cent of the water-free soil.

Use the soil collected according to method given on a previous page and make the determinations in duplicate for surface, subsurface, and subsoil.

Record all data on the opposite page.

Weigh carefully six soil pans. Place in each pan 200 g. of the soil and weigh quickly to avoid loss of moisture by evaporation. Dry at room temperature for 72 hours, after which weigh at intervals of 24 hours until a practically constant weight is obtained. The loss in weight is the capillary moisture. Express results in grams, and after completing the next exercise express results in per cent of water-free soil.

Use these air-dry soils for Practice II.

REFERENCES.
　　"Soils," Lyon and Fippin, pp. 141–148.
　　"The Soil," Hall, A. D., pp. 27–28 and 71–75.
　　"Soils," Hilgard, E. W., p. 195.
　　Bulletin No. 123, Illinois Agricultural Experiment Station, pp. 193–195.

Date of sampling ....

STRATUM	SURFACE		SUBSURFACE		SUBSOIL	
	1	2	1	2	1	2
Weight of pan.						
Weight of pan and soil as it came from field						
Weight of pan and air-dry soil						
Weight of soil as it came from field . . .						
Weight of air-dry soil						
Loss in weight = capillary water						
Average per cent of hygroscopic water as found in Practice No. II						
Weight water-free soil calculated, using above per cent of hygroscopic water						
Capillary water in per cent based on weight of water-free soil						

PRACTICE II

DETERMINATION OF HYGROSCOPIC MOISTURE IN SOILS

Use air-dry soils from Practice I after grinding thoroughly in a mortar.

Weigh the necessary weighing bottles or crucibles which have been made water-free by drying in an oven at 100° C. for five hours. Crucibles may be made water-free in a blast flame. Cool in a desiccator before weighing. It is best to weigh out all of the duplicate samples at the same time, so as to have them under the same moisture conditions. The hygroscopic moisture of soil varies with the temperature and relative humidity of the atmosphere.

Dry in an oven at 100° to 105° C. for at least eight hours. Cool in a desiccator. Weigh rapidly to avoid the absorption of much moisture from the air. The loss in weight is the hygroscopic moisture. Express in tabular form on the opposite page the hygroscopic water in grams and in per cent of water-free soil; also the total moisture in the samples in per cent of water-free soil.

REFERENCES.
"Soils," Lyon and Fippin, pp. 141–144.
"The Soil," Hall, A. D., pp. 84–88.
"Physical Properties of Soil," Warington, Robt., pp. 57–60.
"The Soil," King, F. H., p. 252.

Stratum	Surface		Subsurface		Subsoil	
	1	2	1	2	1	2
Weight of weighing bottle						
Weight of weighing bottle and air-dry soil .						
Weight of weighing bottle and water-free soil						
Weight of air-dry soil						
Weight of water-free soil						
Loss in weight = hygroscopic water . . .						
Hygroscopic water in per cent, based on weight of water-free soil						
Per cent of capillary water as found in Practice No. I						
Total water in per cent						

PRACTICE III

EFFECT OF DRAINAGE ON TEMPERATURE OF A SOIL[1]

Two wooden trays[2] three by four feet and eight inches deep, without legs, the bottom resting on the ground, one lined with zinc to prevent drainage and the other made so as to allow drainage, are filled with the same kind of soil. Water is added to each until drainage begins in the latter.

Each tray should be divided into plots of equal size. After the soil is dry enough to work properly, wheat, corn, watermelons, etc. should be planted in their respective plots in each tray, the same number of seeds in each plot. It is convenient to plant 50 or 100 seeds of each kind in this and the following practice. Each student may look after the planting of a single plot, but should make observations morning and evening on all plots in both trays, and keep accurate records of the number of plants that have come up.

After the plants begin to come up the temperature in each tray at one, two, and four inches in depth is read and recorded hourly on a clear day from 6 A.M. to 6 P.M.

Explain differences in temperature.

Why is clay land so often cold?

Why are these seeds used?

REFERENCES.
"Soils," Lyon and Fippin, pp. 163, 242–244, and 463.
"The Soil," Hall, pp. 130–132.
"Physical Properties of Soil," Warington, pp. 174–178.
"The Soil," King, pp. 225–227 and 237–238.
"Soils," Hilgard, pp. 301 and 307.

[1] This and the following practice logically come later in the course, but the season here makes it necessary to give them early in the first semester, but later in the second semester. Best results may be obtained by conducting these practices before the weather gets too cold in the fall or too hot in the spring.

[2] Where it is possible it may be better to conduct this and the following practice in the field, where the conditions of soil and temperature will be more nearly normal. Instead of the undrained tray a zinc box may be put into the ground. It will then be well to place in this box the soil removed to make room for it. Some frames will be needed to mark the limits of the plots.

Date of readings ....

Time	Thermometer 1 Inch below Surface		Thermometer 2 Inches below Surface		Thermometer 4 Inches below Surface	
	Drained	Undrained	Drained	Undrained	Drained	Undrained
6 a.m.						
7 a.m.						
8 a.m.						
9 a.m.						
10 a.m.						
11 a.m.						
12 m.						
1 p.m.						
2 p.m.						
3 p.m.						
4 p.m.						
5 p.m.						
6 p.m.						

GERMINATION TEST

Time after Planting	Wheat		Corn		Watermelons	
	Drained	Undrained	Drained	Undrained	Drained	Undrained
.... days						
.... days						
.... days						
.... days						
.... days						
.... days						
.... days						

PRACTICE IV

EFFECT OF COLOR ON TEMPERATURE OF A SOIL

Fill a wooden tray three by six feet and eight inches deep with a very light-colored [1] gray silt loam, well pulverized. Divide the tray lengthwise into halves. Divide each half into five or six plots, and plant the same kind of seed — wheat, oats, corn, soy beans, watermelons, etc. — in opposite plots, planting the same number in each. Cover those in one half of the tray three fourths of an inch deep and in the other one half inch deep. Then cover the latter with one fourth inch of black soil so that all of the light-colored soil is covered. Keep all parts of tray equally moist.

The planting, observing, and recording the number of plants up each morning and evening may be done the same as in Practice III.

Place thermometers with bulbs at one, two, and four inches below the surface and one with bulb one inch above the surface, supported in a way that will not affect the temperature. Read and record the temperature hourly from 6 A.M. to 6 P.M.

Which soil shows the higher temperature? Why?

Why can you see the corn rows on low black land sooner after planting than upon the higher lighter colored land?

REFERENCES.
"Soils," Lyon and Fippin, pp. 130 and 456–458.
"The Soil," Hall, pp. 127–128.
"Physical Properties of Soil," Warington, pp. 161–164.
"The Soil," King, pp. 230.

[1] We may get the same results by filling the tray with dark soil, a brown or black silt loam, and by covering the one half with a very light gray silt loam.

PRACTICE IV (Continued)

Date of readings ....

Time	Thermometer 1 Inch above Soil		Thermometer 1 Inch below Surface		Thermometer 2 Inches below Surface		Thermometer 4 Inches below Surface	
	Dark	Light	Dark	Light	Dark	Light	Dark	Light
6 A.M.								
7 A.M. . . . ,.								
8 A.M.								
9 A.M.								
10 A.M.								
11 A.M.								
12 M.								
1 P.M.								
2 P.M.								
3 P.M.								
4 P.M.								
5 P.M.								
6 P.M.								

GERMINATION TEST

Time after Planting	Wheat		Oats		Corn		Soy Beans		Melons			
	Dark	Light	Dark	Light	Dark	Light	Dark	Light	Dark	Light	Dark	Light
.... days												
.... days												
.... days												
.... days												
.... days												
.... days												
.... days												

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DETERMINATION OF TOTAL MOISTURE IN THE SAME SOIL UNDER DIFFERENT CONDITIONS

Three students may work together, one taking the surface, another the subsurface, and the third the subsoil. These results may be compared.

Collect samples of surface, subsurface, and subsoil[1] from the following places: (1) sod, (2) tilled field, (3) forest. In collecting these samples care should be taken to secure them from as small an area as possible, so that the mineral composition of the soil may be uniform. It is essential, also, that the topography, in so far as it affects drainage, should be uniform. Expose the samples to the air as little as possible while taking them.

After taking them to the laboratory the soil should be thoroughly mixed by shaking.

The condition of the weather at the time the samples are taken, and also the amount of rainfall within the week previous, should be noted.

Make the determinations in duplicate. Weigh six soil pans and use 100 g. of each soil. Weigh rapidly to avoid loss by evaporation. Dry at room temperature for forty-eight hours; then place in an oven at 100° C. for at least ten hours. Cool to room temperature and weigh at once. The loss in weight represents the total water content.

Explain differences in moisture content of the soils.

REFERENCES.
   " Soils," Lyon and Fippin, pp. 144–148.
   " The Soil," Hall, pp. 71–75.

[1] In collecting the subsoil for moisture determination it is sometimes well to divide it into two equal parts as to depth.

Date of sampling ....

Name of Student	Surface		Subsurface		Subsoil	
	Sod					
	1	2	1	2	1	2
Weight of pan.						
Weight of pan and soil						
Weight of pan and water-free soil						
Weight of moist soil.						
Weight of water-free soil						
Loss of water in grams						
Per cent of moisture on water-free basis . .						
	Tilled field					
Weight of pan.						
Weight of pan and soil.						
Weight of pan and water-free soil						
Weight of moist soil						
Weight of water-free soil						
Loss of water in grams						
Per cent of moisture on water-free basis . .						
	Forest					
Weight of pan						
Weight of pan and soil.						
Weight of pan and water-free soil						
Weight of moist soil						
Weight of water-free soil						
Loss of water in grams						
Per cent of moisture on water-free basis . .						

PRACTICE VI

DETERMINATION OF THE VARIATION IN THE HYGROSCOPIC MOISTURE OF SOILS

In this exercise each student will use air-dry soils provided for the regular class work. These are sand or sandy loam, gray silt or gray silt loam, brown silt loam, clay or clay loam, and peat.

Determine the weight of moisture lost when heated for eight hours in an oven at 100 to 105° C. This loss is the hygroscopic moisture. Express in per cent based on the weight of water-free soil. All samples, especially duplicates, should be weighed out at the same time to avoid any change in the amount of moisture due to a change in relative humidity or temperature.

For directions in detail see Practice II.

Explain differences between clay or clay loam and sand or sandy loam; between peat and sand or sandy loam.

REFERENCES.
"Soils," Lyon and Fippin, pp. 141–144.
"The Soil," Hall, pp. 84–88.
"Physical Properties of Soil," Warington, pp. 57–60.
"The Soil," King, p. 252.
"Soils," Hilgard, pp. 196–200.

Soils	Sand or Sandy Loam		Gray Silt or Gray Silt Loam		Brown Silt Loam		Black Clay Loam		Peat	
	1	2	1	2	1	2	1	2	1	2
Weight of weighing bottle										
Weight of weighing bottle and air-dry soil . . .										
Weight of weighing bottle and water-free soil . .										
Weight of air-dry soil . .										
Weight of water-free soil .										
Loss in grams = Wt. of hygroscopic water . . .										
Hygroscopic water in per cent on water-free basis										

PRACTICE VII

FLOCCULATING EFFECT OF LIME

Use four shaker bottles with rubber stoppers.

In the first put 200 cc. distilled water as a check, in the second 200 cc. of a 0.025 per cent solution [1] of quicklime (CaO, preferably C.P.), in the third 200 cc. of a 0.05 per cent solution, and in the fourth 200 cc. of a 0.1 per cent solution. Add to each 3 g. of a heavy clay finely ground in a mortar. Agitate for one hour in the mechanical shaker.

After shaking take out a drop from the check and 0.1 per cent solution and examine under a microscope with a high power. Make sketches on data sheet of the arrangement of soil particles.

Then pour some of the contents of the bottles into tubes and whirl in a centrifuge, stopping every two or three minutes to note the effect upon clearness. Whirl for at least ten minutes. Then pour the contents of the tubes back into their respective bottles, shake thoroughly, and set aside. Observe regularly to determine the time required for complete sedimentation in each case.

Which becomes clear first in the centrifuge? Why?

What application of this principle is made in farm practice?

REFERENCES.
     "Soils," Lyon and Fippin, pp. 116 and 352.
     "The Soil," Hall, pp. 38–41.
     "Physical Properties of Soil," Warington, pp. 25–35, especially
       30–32.
     "The Soil," King, p. 30.

[1] These solutions will be made by the instructor.

Date run in centrifuge ....

	Time to become Clear in Centrifuge	Time for Sedimentation
Check — distilled water		
0.025 per cent solution		
0.05 per cent solution		
0.1 per cent solution		

Make sketches of arrangement of soil particles.

Distilled water   0.1 per cent lime solution

DETERMINATION OF THE EFFECT OF LIME ON PLASTIC SOILS

Two students may work together on this experiment.

Weigh out six 300-g. samples of a clay soil.

To sample No. 1, check, add no lime.

To No. 2 add 0.1 per cent, 0.3 g. of powdered quicklime.

To No. 3 add 0.5 per cent, 1.5 g. of powdered quicklime.

To No. 4 add 1.0 per cent, 3.0 g. of powdered quicklime.

To No. 5 add 2.0 per cent, 6.0 g. of powdered quicklime.

To No. 6 add $3\frac{1}{3}$ per cent, 10.0 g. of sand.

Mix the clay and lime thoroughly in a soil pan and add just enough water for maximum plasticity. Cover with a glass plate to reduce loss by evaporation. Set aside to let the lime act for at least twenty-four hours.

Make a test of tenacity, as directed in Practice IX.

After making the tenacity test fill the mold, first placing in it a piece of damp cheesecloth to facilitate the removal of the clay. Make duplicate bricks of each mixture, being careful to compress each to the same degree. Place the bricks on a cloth in a soil pan and dry in an oven for five hours at 100° C.

Test the strength of each brick by supporting the ends so as to allow just 3 inches between the points of support. Suspend weight bag in the middle of brick and determine the weight necessary to break each by pouring shot into the bag.

Explain the effect of lime.

Why does the sand not have as much effect as lime on the breaking strength?

How many tons of lime per acre do the above percentages represent, the surface $6\frac{2}{3}$ inches of soil weighing 2,000,000 pounds?

REFERENCES.
"Soils," Lyon and Fippin, pp. 116–117.
"The Soil," Hall, pp. 40–41.
"Physical Properties of Soils," Warington, pp. 25–35, especially p. 33.
"The Soil," King, p. 30.
"Soils," Hilgard, pp. 59–60.

Test of Strength of Bricks

	First trial	Second trial	Average
Check — no lime			
0.1 per cent, 0.3 g. of lime			
0.5 per cent, 1.5 g. of lime			
1.0 per cent, 3.0 g. of lime			
2.0 per cent, 6.0 g. of lime			
3⅓ per cent, 10.0 g. of sand			

COMPARISON OF TENACITY

Mixture		Check	0.3 Gram Lime	1.5 Grams Lime	3 Grams Lime	6 Grams Lime	10 Grams Sand
Weight to overcome tenacity .	1						
	2						
Average of trials							
Weight to overcome friction . .							
Tenacity							

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PRACTICE IX

TESTING THE TENACITY OF MOIST SOILS

Two students may work together.

Use the gray silt or gray silt loam, brown silt loam, and the clay or clay loam.

Weigh out three 200-g. samples of each soil in a pan, and mix by hand enough water with the first to bring it to a maximum adhesiveness, as near as you can judge.

Carefully measure and record the amount of water used. To the second sample add 10 cc. more water, and to the third 20 cc. more than to the first sample.

Fasten the cages together firmly, pack the moist soil into them, and scrape off level with top of cage. Attach the weight bag, release the movable cage, and pour fine shot into the bag slowly until the soil column breaks. Weigh the bag and shot. Put the movable cage in place, but not having ends of the soil columns in contact with each other, and determine the weight necessary to overcome friction. Subtract this from the previous weight. The result represents the tenacity of a column of moist soil 1 square inch in cross section. Make a duplicate test.

Sample No. 1 made up to maximum tenacity should be used immediately in Practice X.

How does fineness of grain affect tenacity?

What effect has undecomposed organic matter on tenacity?

What term is applied to very tenacious soils?

What are the differences in the working of these soils?

REFERENCES.
 "Soils," Lyon and Fippin, pp. 97–99 and 129.
 "Physical Properties of Soil," Warington, pp. 23–25.

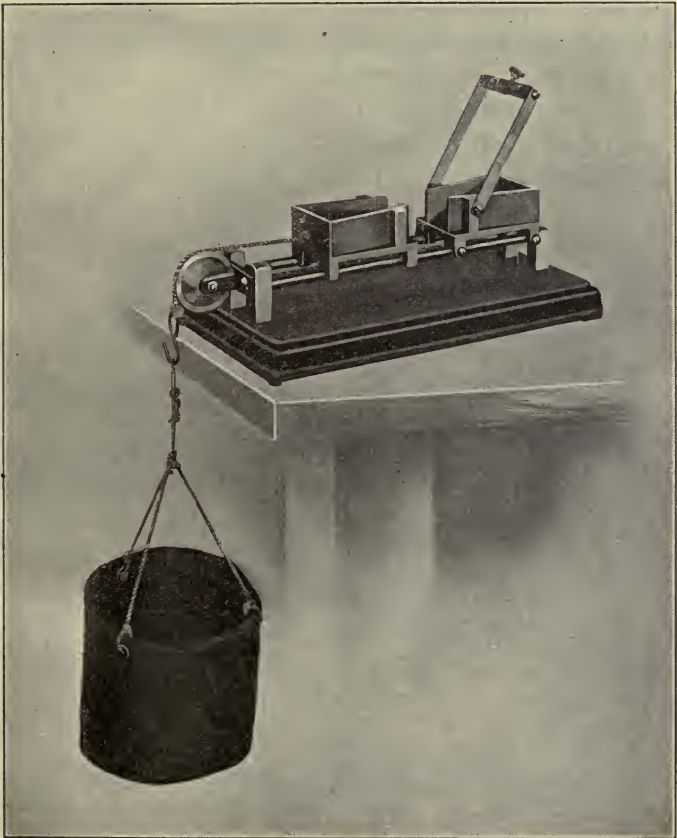| Soils	Gray Silt or Gray Silt Loam			Brown Silt Loam			Clay or Clay Loam		
	1	2	3	1	2	3	1	2	3
Amount of water used									
Weight to overcome tenacity . 1									
2									
Average of trials									
Weight to overcome friction . .									
Tenacity									

Fig. 2. Tenacity-Test Apparatus

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PRACTICE X

DETERMINATION OF SHRINKAGE IN SOILS

Two students may work together.

Weigh out in a small soil pan 200 g. of sand or sandy loam, gray silt or gray silt loam, brown silt loam, clay or clay loam, and peat.

The soil with the quantity of water representing maximum tenacity in Practice IX may be used here if put into the pan while it is still moist.

Mix each sample thoroughly by hand with the right quantity of water to bring about maximum adhesiveness.

Place cheesecloth in the bottom of a pan 3 inches, or 76 mm., square and $\frac{1}{2}$ inch deep. Pack in the soil and scrape it off even with the top of pan. Take out the block of soil on cheesecloth and dry at room temperature for a day or two before placing in the oven at 100° C. for twenty-four hours.

Measure and record the size of the block of dry soil. Calculate the shrinkage and express in per cent of the original area of the block of wet soil.

SOILS		AREA OF SOIL BLOCKS AFTER DRYING	AVERAGE	AREA OF PAN BOTTOM	SHRINKAGE DUE TO DRYING	PER CENT OF SHRINKAGE
Sand	1					
	2					
Silt	1					
	2					
Brown silt loam . . .	1					
	2					
Black clay loam . . .	1					
	2					
Drab clay	1					
	2					
Peat	1					
	2					

What relation exists between size of particles and shrinkage?
What effect has clay and organic matter on shrinkage?

References.
   "Soils," Lyon and Fippin, pp. 98–99.
   "Physical Properties of Soil," Warington, pp. 35–36.
   "Soils," Hilgard, pp. 112–114.

PRACTICE XI

DETERMINATION OF THE APPARENT SPECIFIC GRAVITY OF SOILS

In determining apparent specific gravity the pore space is not taken into account. Then apparent specific gravity is much less, numerically, than real specific gravity. Find the apparent specific gravity of sand or sandy loam, gray silt or gray silt loam, brown silt loam, clay or clay loam, and peat.

Weigh a clean empty soil tube.[1] Fill the tube with one of the soils by simply pouring it in loosely until it reaches the crease near the top, being careful not to compact it by jarring or jolting. Weigh, empty, and then fill again with the same soil in the same way, using the average of the two weights to determine the apparent specific gravity.

Treat each soil in the same way.

Calculate the weight of water-free soil taken in each case by using the average per cent of hygroscopic moisture found in Practice VI. These average figures will be given to the class by the instructor.

Find the volume of the soil tube by filling with water and weighing. The weight in grams will give the volume of the tube in cubic centimeters, since 1 cc. of water weighs approximately 1 g. The weight of the soil divided by the volume of the tube gives the weight of 1 cc. of soil, or the volume weight of the soil. Numerically this is the apparent specific gravity.

Repeat the above process with each soil, but compact the soil. Lift the base on which the tube stands to the 6-inch mark and let it drop. Do this six times. Repeat, refilling each time until tube is full to the crease.

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[1] A brass tube 2 inches in diameter and 12 inches long, closed at one end.

The apparent specific gravity of soils varies with the degree of compaction. A freshly plowed field is much lighter per cubic foot than one compacted by rains, tramping, or by means of the roller.
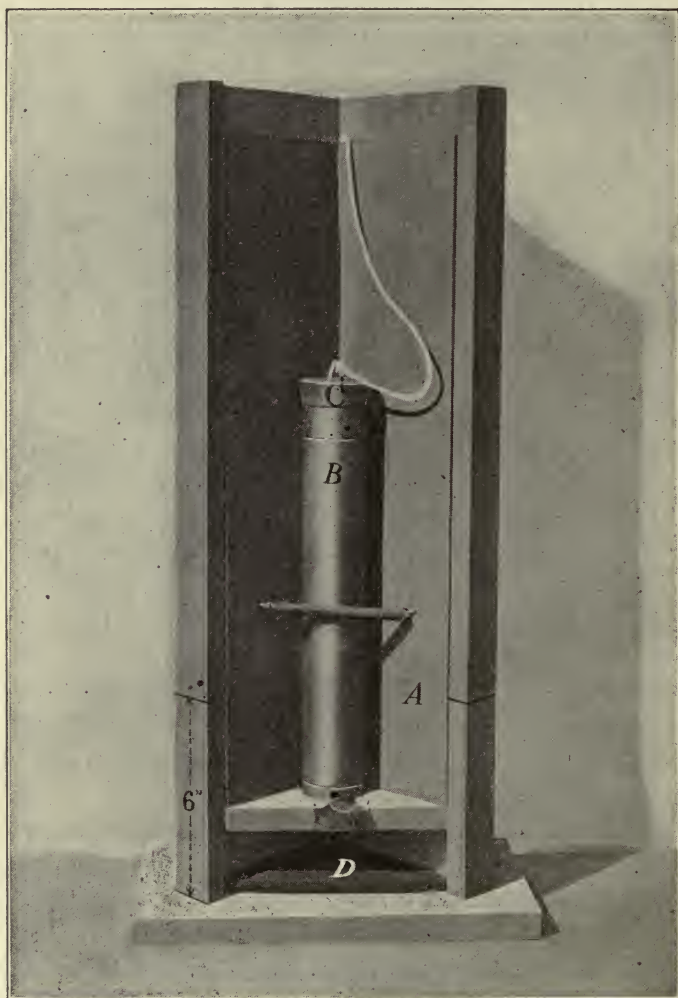
Fig. 3. Soil Compactor

A, movable interior to be lifted, which, by dropping, compacts the soil; *B*, soil tube in place on base of *A*; *C*, rubber stopper closing tube; *D*, felt or rubber cushion

Why is the apparent specific gravity of a sandy soil higher than that of a silt loam?

Why is the apparent specific gravity of peat so low?

Sandy soils have less pore space than clay or clay loams.
How will this affect the apparent specific gravity?

Calculate the weight of a cubic foot of each soil, loose and compact.

References.
    "Soils," Lyon and Fippin, pp. 94–96 and 128.
    "The Soil," Hall, pp. 63–64.
    "Physical Properties of Soil," Warington, pp. 42–44.
    "The Soil," King, p. 85.
    "Soils," Hilgard, pp. 107–108.

SOILS		SAND OR SANDY LOAM		GRAY SILT OR GRAY SILT LOAM		BROWN SILT LOAM		CLAY OR CLAY LOAM		PEAT	
		L[1]	C[1]	L	C	L	C	L	C	L	C
Weight of tube and air-dry soil	1										
	2										
Average of trials . . .											
Weight of tube											
Weight of air-dry soil . .											
Per cent of hygroscopic moisture											
Weight of water-free soil											
No. cc. water to fill tube .											
Apparent specific gravity											
Weight of a cubic foot in pounds											

[1] L = Loose; C = Compact.

DETERMINATION OF APPARENT SPECIFIC GRAVITY OF SURFACE SOIL UNDER FIELD CONDITIONS

Two students may work together, one taking plowed ground, the other sod near by.

Take a tube [1] similar to Fig. 4 and force it into the ground to the depth of 6 inches.

Remove the soil to a weighed pan. Collect another sample of the same soil under identical conditions, using every precaution to have the duplicate similar. Dry at room temperature for a day or two before placing in the oven at 100° C. to dry for twenty-four hours. Calculate the volume of soil taken and divide the weight of water-free soil by this. The result is the apparent specific gravity.

The apparent specific gravity of soils in the field may be taken as an approximate indication of their tilth, since the better the tilth the lower the apparent specific gravity for the same kind of soil. This is due to the fact that soils in good tilth are looser on account of the presence of a larger proportion of organic matter and better granulation. The apparent specific gravity of a continuously cropped soil is higher than that of one on which proper rotations have been practiced. Why?

It will be well to collect samples under varied conditions and have each student secure the results from a number of others and tabulate in his guide for purposes of comparison.

FIG. 4

---

[1] An iron or brass tube 2 or 3 inches in diameter, with a cutting edge.

What is the weight of a cubic foot of soil under the above conditions?

REFERENCES.
  "Soils," Lyon and Fippin, pp. 94–96.
  "The Soil," Hall, pp. 64–65.
  "Physical Properties of Soil," Warington, pp. 44–49.
  "Soils," Hilgard, pp. 107–108.

Soil ....

STUDENT				
CONDITION OF SOIL				
	1	2	1	2
Weight of pan and water-free soil				
Weight of pan				
Weight of water-free soil				
Capacity of tube in cc. = volume of soil				
Apparent sp. gr. based on wt. of water-free soil . . .				
Weight of a cubic foot of soil in pounds				

PRACTICE XIII

DETERMINATION OF REAL SPECIFIC GRAVITY OF SOILS

Each student will use a light and dark soil provided by the instructor.

First determine the hygroscopic moisture as in Practice VI and tabulate on opposite page. Fill a 50-cc. pycnometer to the top of capillary tube in glass stopper with freshly boiled and cooled distilled water whose temperature is known. Wipe pycnometer dry and weigh. Pour out about half of the water and weigh. Add about 5 g. of soil (about half as much in case of peat) and weigh again; the difference is the soil added. In this case the soil need not be weighed accurately beforehand.

Boil *gently* for a few minutes in a water bath, sand bath, or on an asbestos mat to drive out the air from the soil. Refill with distilled water, bring to the same temperature as before, and weigh. From the per cent of hygroscopic water as determined calculate the weight of water-free soil used.

The weight of the pycnometer full of water plus the weight of water-free soil added, minus the weight of the full pycnometer containing the soil gives the weight of water displaced by the soil. Then $\dfrac{\text{weight of water-free soil}}{\text{weight of water displaced}} = $ specific gravity.

Compare real with apparent specific gravity.

Why is the real specific gravity higher?

REFERENCES.
    " Soils," Lyon and Fippin, pp. 94–96.
    " The Soil," Hall, p. 63.
    "Physical Properties of Soils," Warington, pp. 41–42.

Soils								
	1	2	1	2	1	2	1	2
Weight of air-dry soil								
Per cent of hygroscopic water								
Weight of water-free soil								
Weight of pycnometer filled with water								
Weight of pycnometer filled with water + water-free soil								
Weight of pycnometer and soil + water, filled after boiling								
Weight of water displaced								
Specific gravity								

HYGROSCOPIC WATER

Soils								
	1	2	1	2	1	2	1	2
Weight of air-dry soil								
Weight of water-free soil								
Loss in weight = hygroscopic water . .								
Per cent of hygroscopic water								

PRACTICE XIV

DETERMINATION OF POROSITY (FIRST METHOD)

Use sand or sandy loam, gray silt or gray silt loam, brown silt loam, clay or clay loam, and peat.

The weight of soil and volume of tube as found in Practice XI may be used here, or one may weigh a Nessler jar or graduated cylinder and fill to the 100-cc. mark with soil not compacted, and weigh.

Compute the amount of water-free soil, using the average per cent of hygroscopic moisture from Practice VI which was given for Practice XI. The real specific gravity will be determined or furnished by the instructor.

$$\frac{(\text{Volume of soil} \times \text{real specific gravity}) - \text{weight of water-free soil}}{\text{Volume of soil} \times \text{real specific gravity}} \times 100 =$$

per cent of pore space or porosity.

What effect does size of particles have on total amount of pore space?

Does the amount of pore space increase or decrease with the amount of organic matter?

Which of the soils have the largest pores? Does this mean the greatest amount of pore space?

REFERENCES.
> "Soils," Lyon and Fippin, pp. 84–94.
> "The Soil," Hall, pp. 60–63.
> "Soils," Hilgard, pp. 108–109.

Soils	Sand or Sandy Loam		Gray Silt or Gray Silt Loam		Brown Silt Loam		Clay or Clay Loam		Peat	
	L[1]	C[1]	L	C	L	C	L	C	L	C
Weight of cylinder . . .										
Weight of cylinder and air-dry soil 1										
2										
Average of trials . . .										
Average weight of air-dry soil										
Weight of water-free soil										
Per cent of hygroscopic water										
Real specific gravity . .										
Per cent of pore space .										

[1] L = Loose ; C = Compact.

PRACTICE XV

DETERMINATION OF POROSITY (SECOND METHOD)

Find what per cent the apparent specific gravity is of the real specific gravity and subtract this from 100 per cent. The remainder expresses the per cent of pore space in the soil, or its porosity.

Use the real specific gravity and the average figures for apparent specific gravity from Practice XI, as given you by the instructor.

Determine the porosity of the stock soils, loose and compact, and express the results in tabular form.

What relation exists between porosity and apparent specific gravity? Why?

REFERENCES.
"Soils," Lyon and Fippin, pp. 92–93.
"The Soil," Hall, pp. 60–63.

Soils	Sand or Sandy Loam		Gray Silt or Gray Silt Loam		Brown Silt Loam		Clay or Clay Loam		Peat	
	L[1]	C[1]	L	C	L	C	L	C	L	C
Apparent specific gravity .										
Real specific gravity . .										
Per cent of pore space . .										

[1] L = Loose; C = Compact.

PRACTICE XVI

DETERMINATION OF LOSS ON IGNITION

The loss that a soil suffers when it is ignited is often taken as a measure of its organic matter, but it can be only a very rough approximation at best for most soils. For some subsurface and nearly all subsoils it gives little or no idea of the amount of organic matter. By igniting, the organic matter, volatile salts, carbon dioxide of carbonates present, and water of hydration will be driven off. In heavy clay soils and all fine-grained ones water of hydration forms a very large part of the loss. Subsoils with little or no organic matter may lose as much as surface soils, due to the larger amount of clay and consequently a larger amount of water of hydration which is driven off by the heat. The more organic matter present in a soil or the greater the sand content, the nearer the loss on ignition will correspond to the actual organic content, so that for sandy and peat soils ignition may give a close approximation to the amount of organic matter present.

Use the same soils as used in Practice XIII. Bring four small crucibles (25 cc.) to a constant weight by igniting in a blast flame. Weigh out 5-g. duplicate samples of each soil and ignite in the crucibles at a low red heat for one hour in a muffle furnace. Cool in a desiccator and weigh. Calculate the weight of water-free soil used. Express the loss due to ignition in per cent of the water-free soil.

Which soil loses more? Why?

If a coarse- and a fine-grained soil have the same organic content, which will lose more on ignition?

REFERENCES.
  "Soils," Lyon and Fippin, pp. 124–126.
  "The Soil," Hall, p. 43.

Soils								
	1	2	1	2	1	2	1	2
Weight of crucible and air-dry soil . .								
Weight of air-dry soil								
Weight of crucible and water-free soil .								
Hygroscopic moisture in per cent . . .								
Weight of water-free soil								
Weight of soil after ignition								
Loss in grams due to ignition								
Per cent loss on ignition on water-free basis								

PRACTICE XVII

DETERMINATION OF HUMUS IN SOILS

Weigh out 5-g. or 10-g. samples of the air-dry soils used in Practices XIII and XVI. Place on a filter in a funnel and leach out the lime and magnesia with dilute hydrochloric acid.[1] When the lime and magnesia are all leached out as shown by testing the filtrate by collecting a few cubic centimeters of the acid filtrate in a test tube direct from the funnel and adding dilute ammonia drop by drop until the solution is slightly alkaline, the addition of a few drops of ammonium oxalate will produce no precipitate. If lime is present, a white opaque crystalline precipitate is formed. Wash out the hydrochloric acid with distilled water.

Dry the soil and filter at room temperature for a day, then in the oven at 100° C. for 8 hours.

Place soil and filter in a shaker bottle. Add 150 cc. of dilute ammonia[2] for light soils and 250 cc. for dark soils, the amount depending on the quantity of humus in the soil. Shake for 3 hours. Filter.

If evaporation, which would concentrate the filtrate, can be prevented, evaporate 100 cc. of the humus filtrate to dryness and calculate total humus; otherwise evaporate all of the filtrate. In this case care should be taken to wash out with ammonia any humus that may be held mechanically in the soil or filter paper.

Dry the evaporated humus at 100° C. for 5 hours. Weigh, ignite, and weigh again. The loss in weight is the humus. Calculate from the weight of air-dry soil the weight of water-free soil used, and express the humus in per cent of water-free soil.

Of what benefit is a large amount of humus in a soil?

If an acre of soil, $6\frac{2}{3}$ inches deep, weighs 2,000,000 pounds, how many tons of humus in the surface of the above soils?

REFERENCES.

"Soils," Lyon and Fippin, p. 127.
"The Soil," Hall, pp. 42–47.
"The Soil," King, pp. 94–96.
"Soils," Hilgard, pp. 125–140, especially p. 132.
Circular No. 82, Illinois Agricultural Experiment Station.

[1] For dilute hydrochloric acid use 25 cc. hydrochloric acid, sp. gr. 1.19, with 808 cc. of distilled water.

[2] For the ammonia 178 cc. saturated ammonia with 422 cc. of distilled water. These solutions will be prepared by the instructor.

Soils								
	1	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Weight of crucible								
Weight of crucible and air-dry soil . .								
Weight of air-dry soil								
Per cent of hygroscopic water (if needed)								
Weight of water-free soil (calculated) .								
Weight of evaporated filtrate before ignition								
Weight of evaporated filtrate after ignition								
Loss in weight = humus (approximately)								
Total humus of sample								
Per cent of humus								
Average per cent								
Tons of humus per acre								
Pounds of nitrogen per acre in humus .								

PRACTICE XVIII

DETERMINATION OF CONDUCTIVITY OF HEAT IN SOILS

The five regular stock soils are used.

In one end of the tray place the copper vessel for the water and put asbestos board on all sides except the one in contact with the soil. Place the same quantity of water in each copper vessel. Fill the trays with soil. Place thermometers, which read uniformly, with the bulb at a depth of $2\frac{1}{2}$ inches and 1, 2, 3, 4, 5, and 6 inches from the vessel of water. Heat the water with a Bunsen burner through the opening in the bottom of the tray. Remove the burner when the water reaches a temperature of 95° C. and record the temperature of the soil. Record the temperature reached at the end of each five- or ten-minute period for about an hour.

Students may work in sets of five, each taking the temperature in one soil and exchanging with each of the other four for comparison.

Is there any relation between porosity and conductivity?

REFERENCES.
"Soils," Lyon and Fippin, pp. 459–460.
"Physical Properties of Soil," Warington, pp. 168–174.

FIG. 5. APPARATUS FOR DETERMINING CONDUCTIVITY OF HEAT

PRACTICE XVIII (CONTINUED)

STUDENT

SOILS	SAND OR SANDY LOAM	GRAY SILT OR GRAY SILT LOAM	BROWN SILT LOAM	CLAY OR CLAY LOAM	PEAT
Time . . .					
Temperature at 1 inch.					
2 inches . . .					
3 inches . . .					
4 inches . . .					
5 inches . . .					
6 inches from source of heat . . .					

DETERMINATION OF SPECIFIC HEAT OF SOILS

Two students may work together; a special soil may be assigned to each group.

Place about 100 g. of soil in each of the two large weighing bottles (50 mm. in diameter and 45 mm. in height).

This soil need not be weighed.

Dry in oven for at least 24 hours with stopper out of bottle. Replace stopper to prevent soil from absorbing moisture and weigh when cool.

Place in the water bath [1] or oven, which is kept at a constant temperature by a regulator, for 24 hours.

The water value of the calorimeter cup, stirrer, and thermometer is determined.[2]

Place in the cup enough water accurately weighed, or very carefully measured at about 15° C., to make the water value of system and water added exactly 200 g. of distilled water.

Close calorimeter with thermometer and stirrer in place. Stir and read the temperature of water until it becomes constant. Record this temperature.

Remove the cover, quickly take the weighing bottle from the oven or water bath, remove stopper, and pour soil into calorimeter cup quickly but gently, to avoid splashing of water. Close calorimeter with stirrer and thermometer in position. Stir the mixture and read its temperature at half or minute intervals until the temperature becomes constant. Record this temperature.

Weigh the weighing bottle with any adhering soil. The difference between this and the weight of bottle and soil is the exact weight of soil used.

To find the specific heat equate the gain of heat by the water against the loss of heat by the soil.

It may be well to determine specific heat of the soils with a definite proportion of water added (say 15 to 25 per cent).

[1] The Dr. Lillie water bath made by the Spencer Lens Co., or any oven in which the temperature may be kept constant. It should be so arranged that opening the door to remove or put in soils will have a minimum effect on the temperature of the soils already in the oven.

[2] Weigh the cup and calculate its water value from the specific heat of the material of which it is composed. Do the same for that part of the stirrer and thermometer which will be immersed in the mixture. These weights must be estimated from the total weight of stirrer and thermometer.

Each student may secure the specific heat of the stock soils other than his own from members of the class and tabulate in guide and on data sheet for comparison.

What is the effect of water or organic matter in soil on its specific heat?

References.
"The Soil," Hall, pp. 128–129.
"Soils," Hilgard, p. 301.

Soil	1	2
Weight of weighing bottle and soil . . .		
Weight of bottle		
M = Weight of water-free soil		
T = Temperature of soil		
t = Temperature of water in calorimeter before receiving soil		
O = Constant temperature of water and soil mixed in calorimeter		
m = Grams of water used + water value of calorimeter		
C = Specific heat		

Formula $= C = \dfrac{m(O - t)}{M(T - O)}$

SPECIFIC HEAT OF STOCK SOILS

Soils	Dry	Wet
Sand or sandy loam		
Gray silt or gray silt loam		
Brown silt loam		
Clay or clay loam		
Peat		

THE POWER OF LOOSE SOILS TO RETAIN CAPILLARY WATER

Use the five stock soils.

Place disks of damp cheesecloth in the bottom of the tubes [1] and weigh them. Fill the tubes up to the crease (except peat, two thirds full) 1 inch from the top by pouring the soil in gently through a funnel as the tube is held vertically, being careful not to compact the soil by jarring. Weigh the filled tubes and place in an empty galvanized-iron box. Pour water into the box until on a level with the soil in the tubes, thus allowing it to come up through the soils.

Note the time required for the soils to become moist on top. When the soils have become thoroughly saturated, remove the tubes, wipe dry, and weigh at once to get the total water capacity.

Cover the tubes with watch glasses or glass plates and set them out to drain. Weigh when drainage ceases. The difference between this weight and the weight of tube and air-dry soil is the capillary water retained.

Calculate the weight of water-free soil by using the average per cent of hygroscopic water given you from Practice VI.

Measure depth of settled soils.

Calculate the per cent of capillary water retained. Using the average apparent specific gravity given you from Practice XI, find the weight of a cubic foot of soil. From this and the per cent of water retained, calculate the weight of water retained per cubic foot and the acre inches of water retained.

Land recently plowed 6 inches deep will absorb how many inches of rain without any run-off?

Is there any advantage in deep plowing on rolling or hilly land?

Why do they plow deep in semiarid regions?

What is a saturated soil?

REFERENCES.
   "Soils," Lyon and Fippin, pp. 136–144 and 154–158.
   "The Soil," Hall, p. 67.
   "Physical Properties of Soil," Warington, pp. 64–85.
   "The Soil," King, pp. 157–162 and 187–189.
   "Soils," Hilgard, pp. 229–230.

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[1] Brass, copper, or galvanized-iron tubes 2 inches inside diameter and 12 inches long, with a crease 1 inch from the top. The bottom is perforated with numerous small holes and is about ½ inch from lower end of tube. There are two or three notches or holes in the main tube below the bottom for water to enter.

Soils	Sand or Sandy Loam	Gray Silt or Gray Silt Loam	Brown Silt Loam	Clay or Clay Loam	Peat
Time required for soil to become moist on surface					
Depth of dry soil					
Depth of wet soil					
Weight of tube					
Weight of tube and air-dry soil					
Weight of air-dry soil					
Weight of tube and wet soil					
Weight of tube and wet soil after drainage ceases					
Weight of capillary water retained, difference in wt. of air-dry soil and wet soil drained .					
Per cent of hygroscopic water					
Weight of water-free soil					
Per cent of capillary water retained on water-free basis					
Apparent specific gravity					
Weight of a cubic foot of dry soil					
Pounds of water per cubic foot					
Acre inches of water					
Acre inches of water held by 6 inches of soil .					

PRACTICE XXI

THE POWER OF COMPACT SOILS TO RETAIN
CAPILLARY WATER

Use the five stock soils.

Prepare the tubes in the same way as in Practice XX, but *compact* the soil as directed in Practice XI. Fill tubes to the crease (except peat two-thirds full) and place in the same galvanized-iron box with the tubes in Practice XX.

Calculate the per cent of capillary water, the pounds of water per cubic foot, and the acre inches of water retained.

Which soil becomes wet on top first? Why?

Which soil is drained first? Why?

How does this correspond to total pore space?

How does rolling affect the water-holding capacity of a soil?

REFERENCES.

Same as for Practice XX.

" The Soil," Hall, pp. 105–107.

Soils	Sand or Sandy Loam	Gray Silt or Gray Silt Loam	Brown Silt Loam	Clay or Clay Loam	Peat
Time required for soil to become moist on surface					
Weight of tube					
Weight of tube and air-dry soil					
Weight of air-dry soil					
Weight of tube and wet soil					
Weight of tube and wet soil after drainage ceases					
Weight of capillary water retained, difference in wt. of air-dry soil and wet soil drained .					
Per cent of hygroscopic water					
Weight of water-free soil					
Per cent of capillary water retained on water-free basis					
Apparent specific gravity					
Weight of a cubic foot of soil					
Pounds of water per cubic foot					
Acre inches of water held by acre foot of soil					
Inches of water held by 6 inches of soil . .					

EFFECT OF ORGANIC MATTER ON RETENTION OF CAPILLARY WATER

Two students may work together, using the same tubes as in Practices XX and XXI.

Mix the soil and organic matter thoroughly for each tube in a large pan.

Fill tubes as follows:

No. 1, sand or other soil.

No. 2, 95 per cent sand and 5 per cent organic matter.

No. 3, 90 per cent sand and 10 per cent organic matter.

No. 4, 80 per cent sand and 20 per cent organic matter.

No. 5, 60 per cent sand and 40 per cent organic matter.

The soil and organic matter should be mixed by weight on basis of water-free material.

The apparent specific gravity of these mixtures may be determined as in Practice XI or calculated from average figures furnished by instructor.

Treat as in Practices XX and XXI.

Determine the weight of capillary water retained. Express in per cent on water-free basis and in acre inches.

Find the weight of water held by 1 g. of soil in tube No. 1. Find the weight of water held in the mixtures that was due to soil on this basis and credit the remaining water to the organic matter.

Divide the weight of water (in grams) retained due to the organic matter, by the weight (in grams) of organic matter. This gives the grams or unit of water held by 1 g. or unit of organic matter.

On the basis of the mixture of soil and 5 per cent of organic matter, how many tons of organic matter will be required to increase the water-holding capacity of this soil by 1 inch?

To secure more data on the effect of organic matter one group of students may use sand and organic matter loose, another group the same mixture compact. All of the stock soils should be treated in the same manner.

Each student should secure from members of the class this data for each of the stock soils, loose and compact, and tabulate in his manual and on data sheet for comparison.

What bearing does this practice have on prevention of destructive erosion ?

References.
"Soils," Lyon and Fippin, pp. 129–130 and 153.
"The Soil," Hall, pp. 117–118.
Circular No. 119, Illinois Agricultural Experiment Station.

Soil		.... 95% Organic Matter 5%	.... 90% Organic Matter 10%	.... 80% Organic Matter 20%	.... 60% Organic Matter 40%
Time required for soil to become moist on surface					
Weight of tube					
Weight of tube and air-dry soil . .					
Weight of air-dry soil					
Weight of tube and wet soil . . .					
Weight of capillary water retained .					
Per cent of hygroscopic moisture — average for mixture					
Weight of water-free soil					
Per cent of capillary water retained .					
Apparent specific gravity — average for mixture					
Weight of a cubic foot of soil . . .					
Pounds water retained per cubic foot					
Acre inches of water					
Grams or unit of water retained by 1 g. or unit of organic matter . .					

PRACTICE XXIII

DETERMINATION OF THE RATE OF PERCOLATION OF AIR THROUGH SOILS

This Practice may be done as a class exercise, the instructor arranging the apparatus, and the student making frequent observations.

This experiment requires the utmost care in order to obtain satisfactory results. Use "pressure" or "double-thickness" tubing.

Fill the tubes very carefully without compacting, holding them vertically while filling. Use sand, brown silt loam, gray silt or gray silt loam, clay or clay loam, and peat. Connect the soil tube with the top of the aspirator bottle. Be sure that all connections are air-tight. Open the cock, allowing the force of gravity to draw the water out of bottle by pulling air in through the soil in the tubes. Note and record the time required to collect 1 liter of water. Repeat with the soil compacted as in Practice XI. Repeat both loose and compact with sand and 10 per cent peat, gray silt or gray silt loam with 10 per cent peat, brown silt loam and 10 per cent peat, loess, and loess and 10 per cent peat.

It may be tried by wetting the soil.

What bearing has this practice upon aëration?

What effect has organic matter on aëration?

What effect will moisture have on aëration?

References.

"Soils," Lyon and Fippin, pp. 416–417 and 437–446.

"The Soil," King, pp. 239–252.

'Soils," Hilgard, pp. 279–280.

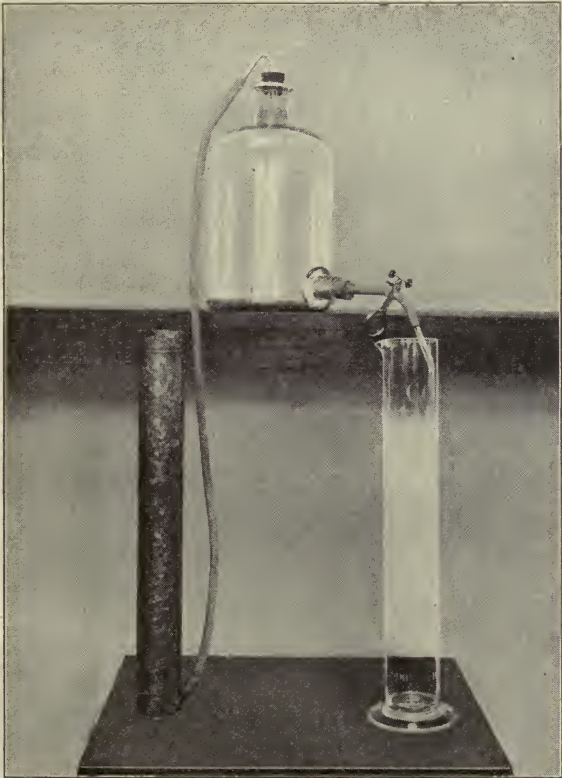| Soils		Sand or Sandy Loam	Gray Silt or Gray Silt Loam	Brown Silt Loam	Clay or Clay Loam	Peat
Time (minutes) for 1 liter to come through . . .	Loose					
	Compact					
Loose Soil, Wet						
Mixtures		Sand + 10% Peat	Gray Silt + 10% Peat	Brown Silt Loam + 10% Peat	Loess	Loess + 10% Peat
Time for 1 liter to come through	Loose					
	Compact					

Fig. 6. Aspirator Apparatus (modified) (after McCall)

PRACTICE XXIV

DETERMINATION OF THE RATE OF PERCOLATION OF WATER THROUGH SOILS

Use sand or sandy loam, gray silt or gray silt loam, and brown silt loam.

Fill the percolator tubes, without compacting, to within one inch of the intake and overflow tubes. Place a half-inch layer of coarse sand on top of soil to prevent disturbance of the soil by the flowing water.

Connect the tubes as in Fig. 7. Attach one side to the water supply; the other should lead to the waste pipe or sink, for taking off the overflow. Allow the water to flow over the surface of the soil just fast enough to keep it constantly flooded. Place flasks under the percolator tubes to catch the drainage water.

Note the time when the water is turned on and also when drainage begins.

When the flow becomes constant, measure the quantity of water draining from the soil in 30 minutes.

Repeat with the same soils in the same way, but compact them in the usual manner.

What application of this experiment do we see in farm practice?

From this experiment would it be advisable to plow deep?

What objection to a sandy soil does this experiment show?

REFERENCES.
"Soils," Lyon and Fippin, pp. 141, 166–169, and 191–194.
"The Soil," Hall, pp. 70 and 75–79.
"Physical Properties of Soil," Warington, pp. 85–91.
"The Soil," King, pp. 170–173.
"Soils," Hilgard, pp. 221–226.

Soils	Sand or Sandy Loam		Gray Silt or Gray Silt Loam		Brown Silt Loam	
	L [1]	C [1]	L	C	L	C
Time required for percolation to begin						
Cubic centimeters of water percolating through in 30 minutes **1**						
Cubic centimeters of water percolating through in 30 minutes **2**						
Average of trials						

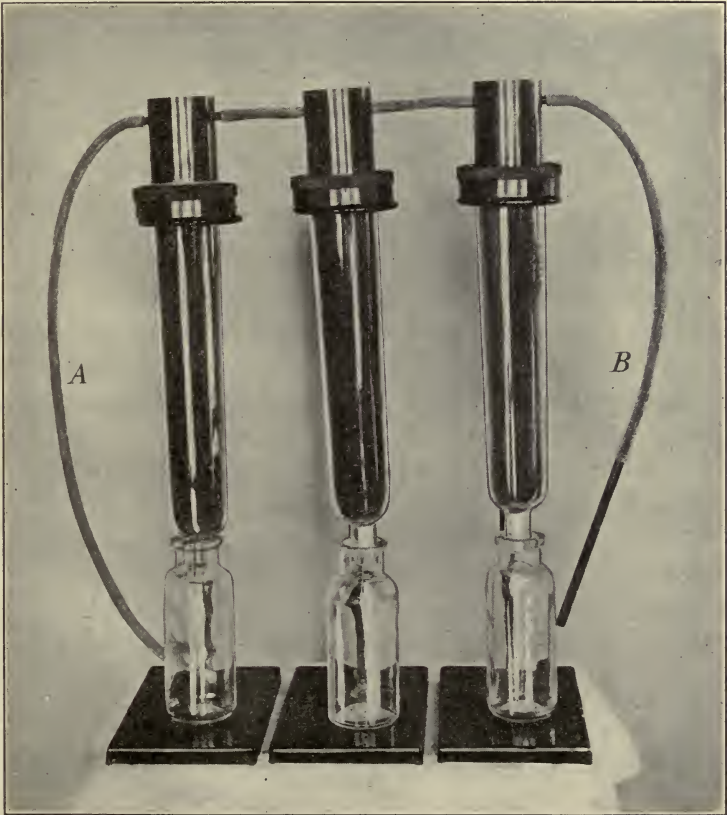[1] L = Loose; C = Compact.

Fig. 7. Percolation Apparatus (modified) (after McCall)
A, intake tube; *B*, overflow tube

PRACTICE XXV

EFFECT OF A LAYER OF ORGANIC MATTER ON RISE OF WATER

Class exercise to be arranged by the instructor.

Each student will record daily the height to which the water has risen in the tubes, and note the effect of organic matter.

Over one end of 24-inch double-thickness glass tubes $1\frac{1}{2}$ to 2 inches in diameter place a 2-ply or 3-ply disk of cheesecloth, using a rubber band to hold it in place. Fill to a depth of 16 or 17 inches with a silt loam, compact as in Practice XI, then add soil and compact until the soil stands at 17 inches in all the tubes. Great care must be taken to have the compaction uniform in all the tubes.

Tube No. 1 is the check.

To tube No. 2 add one-half-inch layer of well-decomposed organic matter, such as rotted manure or peat.

To tube No. 3 add one-half inch of manure or peat and mix with two or three inches of soil.

To tube No. 4 add an inch layer of coarse, undecomposed organic matter, such as chopped straw, coarse sawdust, or fine shavings.

To tube No. 5 add an inch of the same material as in No. 4 and mix as in tube No. 3.

Complete the filling and compact somewhat further, treating all alike. Support the tubes in such a manner that the soil will be held in place and yet have free access to the water in tray. This arrangement will help to prevent the breaking of the soil columns. Note the effect of the organic matter.

Plot curves of the daily rise of water during the first 14 days, or until the water reaches the top of soil.

What is the effect of plowing under poorly rotted manure in the spring?

What advantage is there in disking before plowing?

What advantage in this respect is there in fall plowing?

REFERENCES.
    "Soils," Lyon and Fippin, pp. 153, 164–166, and 169.
    "The Soil," King, pp. 173–178.

HEIGHT TO WHICH WATER HAS RISEN (INCHES)

Time after start-ing experiment	Date	Soil check	Half-inch layer of decomposed organic matter	Half-inch layer of decomposed organic matter well mixed with soil	Inch layer of coarse organic matter	Inch layer of coarse organic matter well mixed with soil
24 hours						
48 hours						
3 days						
4 days						
5 days						
6 days						
7 days						
8 days						
9 days						
10 days						
11 days						
12 days						
13 days						
14 days						
3 weeks						
4 weeks						

PRACTICE XXVI

A STUDY OF THE CAPILLARY POWER OF DIFFERENT GRADES OF SAND

A class exercise to be arranged by the instructor.

Place cheesecloth over the end of 1-inch glass tubes $1\frac{1}{2}$ meters or 5 feet in length, as directed in Practice XXV. Fill tubes to a depth of from 30 to 36 inches, and compact by dropping four times a distance of 4 inches on a book with covers removed. Great care must be taken to have compaction uniform.

Tube No. 1 is filled with white sand passing through a sieve with 100 meshes to the inch, but not through 120 meshes.

Tube No. 2 with sand passing an 80-mesh sieve, but not a 100-mesh.

Tube No. 3 with sand passing a 60-mesh, but not an 80-mesh.

Tube No. 4 with sand passing a 40-mesh, but not a 60-mesh.

Tube No. 5 with sand passing a 20-mesh, but not a 40-mesh.

Place the tubes in the supporting frames in such a manner that the ends shall dip one-half inch beneath the surface of the water contained in the tray. The experiment is now ready for observation, and the data to be obtained at each reading is the total height to which the water has risen. The readings are to be taken as nearly as possible at the intervals stated below and tabulated.

A large class may be divided into groups. Each group will be assigned a definite time to take readings and will record same on a data sheet. Readings should be taken at 10-minute intervals after the water is turned on. Each student will secure all the data and plot curves to hand in with data sheet.

What relation between size of particles and rapidity of rise of water? between size of particles and height to which the water ultimately rises?

REFERENCES.

"Soils," Lyon and Fippin, pp. 169–189.

"The Soil," Hall, pp. 71–75 and 97–99.

"Physical Properties of Soil," Warington, p. 92.

"The Soil," King, pp. 136–142, 173–178, and 194–195.

"Soils," Hilgard, pp. 202–207.

			Height to which Water has risen (Inches)				
	No. of Tube		1	2	3	4	5
Number of reading	Time after starting experiment	Time of each reading	100-mesh sand	80-mesh sand	60-mesh sand	40-mesh sand	20-mesh sand
1	10 minutes						
2	20 minutes						
3	30 minutes						
4	40 minutes						
5	50 minutes						
6	60 minutes						
7	70 minutes						
8	80 minutes						
9	90 minutes						
10	100 minutes						
11	110 minutes						
12	120 minutes						
13	130 minutes						
14	140 minutes						
15	150 minutes						
16	160 minutes						
17	170 minutes						
18	180 minutes						

PRACTICE XXVII

A STUDY OF THE CAPILLARY POWER OF SOILS

A class exercise to be arranged by the instructor.

The capillary power of soils is influenced by several factors, the most important being their physical composition, texture, and compactness. In field soils all of these are changed by continuous cropping, and capillary action is therefore altered. Of these factors physical composition is most important.

Prepare the tubes as in the preceding Practice.

Tubes $1\frac{1}{2}$ to 2 inches in diameter are better for this and the succeeding Practice than smaller tubes.

Fill tube No. 1 with the stock sand or sandy loam.

Fill tube No. 2 with brown silt loam.

Fill tube No. 3 with clay or clay loam.

Fill tube No. 4 with loess.

Fill tube No. 5 with sand 50 per cent and loess 50 per cent.

Fill tube No. 6 with sand 50 per cent and clay 50 per cent.

Fill tube No. 7 with sand 90 per cent and peat 10 per cent.

Fill tube No. 8 with loess 50 per cent and clay 50 per cent.

Fill tube No. 9 with loess 90 per cent and peat 10 per cent.

Fill tube No. 10 with clay 90 per cent and peat 10 per cent, all finely pulverized and air-dry.

Great care must be exercised in filling these tubes not to separate the coarse particles and granules from the finer material, especially in the mixtures. The mixtures may be made in a large pan or by running through a grinder. Uniform filling may best be accomplished by holding the tube perpendicularly while pouring the soil in through a funnel. The tubes may be compacted and supported as in the preceding Practice. Uniformity in compaction is very important.

Readings may be made by students in groups as in the preceding Practice and recorded on a sheet posted for the purpose, recording the total height to which water has risen at the end of 1 hour, 2 hours, 3 hours, 6 hours, 9 hours, 12 hours, 24 hours, and each day following for at least 14 days.

Plot curves, using the data obtained at the end of 24 hours and up to and including that secured on the fourteenth day.

Why does loess show a more rapid rise than clay?

At the end of 1 hour which shows the greater rise, clay or the 20- to 40-mesh sand? Which at the end of a week? Why?

REFERENCES. The same as given under Practice XXVI.

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Height to which Water has risen (Inches)

No. of Tube	1	2	3	4	5	6	7	8	9	10
Time after starting experiment	Sand or sandy loam	Brown silt loam	Clay or clay loam	Loess	Loess, 50% Sand, 50%	Sand, 50% Clay, 50%	Sand, 90% Peat, 10%	Loess, 50% Clay, 50%	Loess, 90% Peat, 10%	Clay, 90% Peat, 10%
1 hour										
2 hours										
3 hours										
6 hours										
9 hours										
12 hours										
1 day										
2 days										
3 days										
4 days										
5 days										
6 days										
7 days										
8 days										
9 days										
10 days										
11 days										
12 days										
13 days										
14 days										
3 weeks										
4 weeks										

EFFECT OF ORGANIC MATTER ON RISE OF CAPILLARY WATER

A class exercise to be arranged by the instructor.

It is best to use glass tubes $1\frac{1}{2}$ to 2 inches in diameter.

Fill, compact, and set up, as in the preceding practice:

Tube No. 1, gray silt or gray silt loam.

Tube No. 2, gray silt or gray silt loam 95 per cent plus 5 per cent peat.

Tube No. 3, gray silt or gray silt loam 90 per cent plus 10 per cent peat.

Tube No. 4, gray silt or gray silt loam 85 per cent plus 15 per cent peat.

Tube No. 5, gray silt or gray silt loam 80 per cent plus 20 per cent peat.

Tube No. 6, gray silt or gray silt loam 65 per cent plus 35 per cent peat.

Tube No. 7, gray silt or gray silt loam 50 per cent plus 50 per cent peat.

Tube No. 8, peat.

Tube No. 9, a virgin sod.

Tube No. 10, heavily cropped not rotated, the same as the virgin soil and collected as near to it as possible.

Compact as uniformly as possible. Take the readings at the same intervals, record and plot curves as in the preceding practice. Plot a separate set of curves for the virgin and the heavily cropped soils.

REFERENCES.

The same as given under Practice XXVI.

HEIGHT TO WHICH WATER HAS RISEN (INCHES)

No. of Tube	1	2	3	4	5	6	7	8	9	10
Time after starting experiment	Silt	Silt, 95% Peat, 5%	Silt, 90% Peat, 10%	Silt, 85% Peat, 15%	Silt, 80 % Peat, 20%	Silt, 65% Peat, 35%	Silt, 50% Peat, 50%	Peat	Virgin sod	Heavily cropped
1 hour										
2 hours										
3 hours										
6 hours										
9 hours										
12 hours										
1 day										
2 days										
3 days										
4 days										
5 days										
6 days										
7 days										
8 days										
9 days										
10 days										
11 days										
12 days										
13 days										
14 days										
3 weeks										
4 weeks										

EFFECT OF VARIED QUANTITIES OF SALTS IN SOLUTION ON
RAPIDITY AND HEIGHT OF RISE OF CAPILLARY WATER

A class exercise to be arranged by the instructor.

Use soils with a low organic content, as the rise of salt solutions is quite irregular in soils containing considerable quantities of organic matter.

In tube No. 1 of each soil use distilled water.

In tube No. 2, normal sodium chloride.[1]

In tube No. 3, three times normal sodium chloride.

In tube No. 4, five times normal sodium chloride.

In tube No. 5, a normal solution of the following: sodium chloride, sodium carbonate, sodium nitrate, sodium sulfate, potassium nitrate, and potassium chloride.

In tube No. 6, three times normal of same mixture.

This might be multiplied indefinitely, but these should give a fair idea of the movement of salts in soils under laboratory conditions.

The tubes are filled with the same care as to uniform compaction, set up, and readings taken as in the three preceding practices.

REFERENCES.

" Physical Properties of Soil," Warington, pp. 211–231.

"Principles and Practice of Agricultural Analysis," Wiley, Vol. I, p. 170.

Bulletin No. 10, United States Department of Agriculture, Division of Soils, p. 20.

[1] See footnote under Practice XXXV.

HEIGHT TO WHICH WATER HAS RISEN (INCHES)

No. of Tube	1	2	3	4	5	6	7	8	9	10	11	12
Time after starting experiment	Dis-tilled water	N NaCl	3 N NaCl	5 N NaCl	N Mix-ture	3 N Mix-ture	Dis-tilled water	N NaCl	3 N NaCl	5 N NaCl	N Mix-ture	3 N Mix-ture
1 hour												
2 hours												
3 hours												
6 hours												
9 hours												
12 hours												
1 day												
2 days												
3 days												
4 days												
5 days												
6 days												
7 days												
8 days												
9 days												
10 days												
11 days												
12 days												
13 days												
14 days												
3 weeks												
4 weeks												

Fig. 8

A, lower section; *B*, second section showing joint; *C*, perforated bottom of *A*

DETERMINATION OF PER CENT OF CAPILLARY WATER AT DIFFERENT HEIGHTS ABOVE THE WATER TABLE

Students may be assigned to work in groups, using the stock soils.

Place a disk of cheesecloth in bottom of tube.

Fill a brass tube cut in 4- or 6-inch sections, according to the accompanying cut, with the soil to be studied. Compact by letting the filled tube drop a distance of 4 inches four times on a book with covers removed. Place the base in a pan of water and allow the water to rise by capillarity.

When the water has reached the surface take the tube apart and place the soil from each section in a weighed pan. Set out to dry at room temperature for 24 hours. Place in an oven for 24 hours. Cool partially and weigh.

On the basis of the water-free soil calculate the percentage of total water held, and by deducting the percentage of hygroscopic water find the actual percentage of capillary water held. Find also pounds per cubic foot and acre inches held in each section.

Why is there any difference in the amount of water held at different distances above the water table?

REFERENCES.

"Soils," Lyon and Fippin, pp. 148–149.

"Physical Properties of Soil," Warington, pp. 77–79.
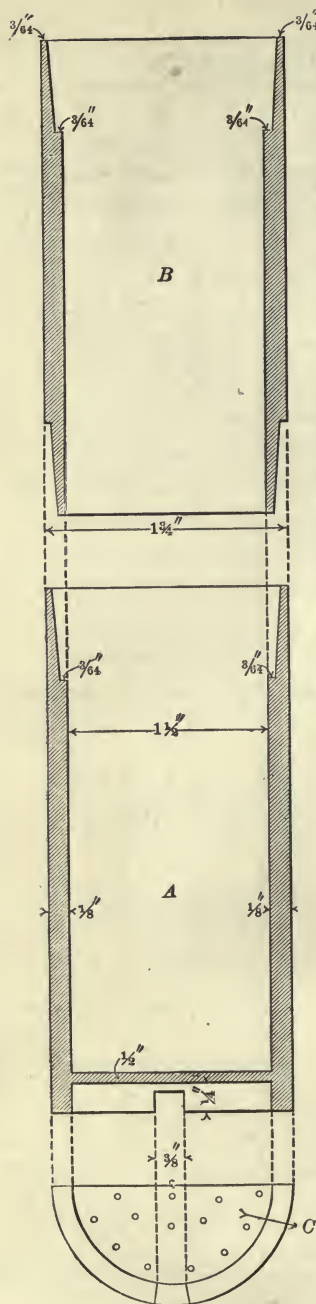
"The Soil," King, p. 157.

"Soils," Hilgard, pp. 207–208.

No. of Sec-tion	Weight of Pan Empty	Weight of Pan + Wet Soil	Weight of Pan + Water-Free Soil	Weight of Total Water Lost	Weight of Water-Free Soil	Per Cent of Total Water Lost	Per Cent of Capil-lary Water	Pounds of Capil-lary Water per Cubic Foot	Acre Inches
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									

Two weeks will be devoted to studying the physical composition of a large number of soils. It is quite important that one should be able to estimate approximately the proportion of gravel, sand, silt, clay, and organic matter in soils, and it is the object of this exercise to enable the student to do this.

Each student will be given a sample of the same soil to be studied according to the outline below.

The work is to be done rapidly, and the graduated cylinder may be used as an aid in estimating the amount of each constituent. Place 10 cc. of soil with 75 to 90 cc. of water in the cylinder.

Shake thoroughly and allow it to stand one-half minute or longer. Note the amount of sand in cubic centimeters and estimate the percentage from this.

The cylinder is an aid in sandy soils but is of little value with silt or clay soils.

    Dry
        Color
        Pulverulent, crumbly, or cloddy
    Moist
        Color
        Floury, mealy, or gritty
        Friable or plastic
    Composition (estimated)
    Organic matter in per cent...
    Gravel in per cent ....
    Coarse and medium sand in per cent ....
    Fine sand in per cent...
    Silt and clay in per cent...

PRACTICE XXXII

STANDARDIZATION OF THE EYEPIECE MICROMETER

Use eyepiece and stage micrometers.

Place both micrometers in position and determine for each of the objectives the number of divisions or spaces of the eyepiece micrometer that corresponds to 1, 0.1, 0.01, and 0.001 millimeters of the stage micrometer.

Show on the table below the number of spaces of the eyepiece micrometer that corresponds to the size of the various grades of soil particles. By means of this table and the microscope with the eyepiece micrometer it may be determined whether the separations are properly made in the following practice.

Grades	Diameter in Millimeters	Number of Spaces in............Mm. or Inch Objective	Number of Spaces in............Mm. or Inch Objective
Clay	less than 0.001		
Fine silt.	0.001 to 0.0032		
Medium silt	0.0032 to 0.01		
Coarse silt	0.01 to 0.032		
Fine sand	0.032 to 0.1		
Medium sand.	0.1 to 0.32		
Coarse sand	0.32 to 1.0		
Fine gravel	1.0 to 3.2		
Medium gravel	3.2 to 1.0		
Coarse gravel.	1.0 to 32		
Stones	32 and larger		

PRACTICE XXXIII

MECHANICAL ANALYSIS

Four samples of from 5 to 10 g. of the prepared soil ground with a rubber pestle are weighed out and the hygroscopic moisture determined.

Two of these are then ignited and the per cent of loss on ignition is found, based upon the water-free soil. Each of the other two samples is placed in a shaker bottle and about 200 cc. of distilled water and from 5 to 10 cc. of ammonia are added. The bottles are then placed in the shaker and agitated until a microscopic examination of a drop of the contents shows that the soil particles are completely separated and no granules exist. When this condition is reached the individual particles will appear clear or semitransparent in the field of the microscope, while any remaining granules will be dark, irregular, and opaque. It may be necessary to continue the shaking for 12 or even 24 hours to completely disintegrate the soil granules. As the determination is quantitative, only a small amount of the liquid is taken from the bottle with a small glass tube and mounted on a slide for examination. When the examination is completed, the slide and cover glass are carefully rinsed with distilled water back into the bottle to recover the small portion of soil taken. Great care is necessary throughout the analysis to prevent the loss of any part of the sample, and for purposes of comparison and greater accuracy in results duplicate samples are used.

When the microscope reveals that no compound granules remain, the samples are ready for separation into the different grades. Transfer soil and water from shaker bottles to two-quart milk bottles.. Remove stoppers from the shaker bottles and
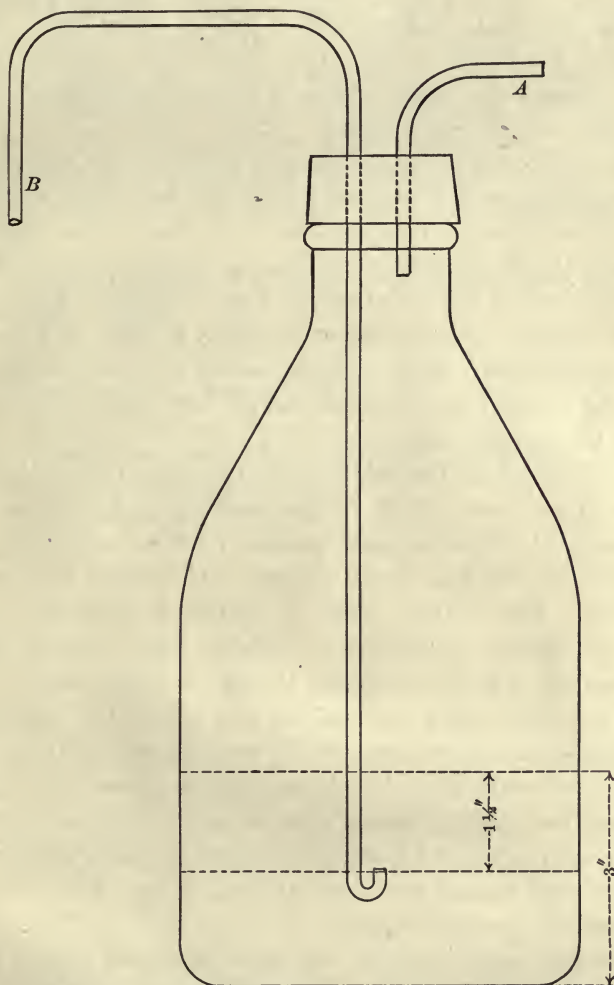

Fig. 9. Bottle for Mechanical Analysis

A, tube for compressed-air connection; B, delivery tube

wash them off carefully with distilled water so as to save all of the adhering particles. Make an apparatus similar to that shown in the figure, using an inverted two-hole rubber stopper so large that it will close the mouth of the bottle without going in.

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Place in one hole a short bent tube and in the other a long tube that reaches near the bottom of the bottle. The lower end of this tube should bend suddenly upon itself so that the opening shall be upward and not downward. Adjust this tube when the apparatus is in place on the bottle so that the opening in the long tube will be $1\frac{1}{2}$ inches from the bottom of the bottle. Make a mark on the bottle 3 inches from the bottom, and fill to this mark by means of a small stream of water of sufficient force to thoroughly stir up the contents.

After the liquid has stood long enough for the fine sand to settle below the end of the tube, as shown by a microscopic examination of a sample compared with the sizes of the grades as determined in the preceding exercise, the liquid is blown off into a beaker provided for the purpose. Pour this into a large glass-stoppered bottle. This operation of filling, settling, and blowing off is repeated until the grades that settle are free from silt and clay. The liquid blown off contains silt and clay, and no effort is made to separate them here.

For separating the fine sand, fill the bottles as before and allow them to stand long enough for the medium and coarse sand to settle below the $1\frac{1}{2}$-inch mark, as shown by the microscope, and then blow off the fine sand. Repeat until all the fine sand is blown off. The medium sand is separated from the coarser grades by washing it through a 0.32-mm. sieve, and the coarse sand from the gravel by washing through a 1-mm. sieve.

If at any time during the analysis it is found that some of the larger grades are blown over, it will be necessary to recover this.

The water containing the silt and clay is poured into a large bottle and thoroughly shaken, when an aliquot part or one tenth is taken and evaporated to dryness, placed in a weighed crucible, ignited, weighed, and the total amount of clay and silt determined and the per cent found.

The water, containing the fine sand, sand and gravel, is decanted, each grade is put in a weighed crucible, dried, ignited, and the per cent of each grade is determined.

REFERENCES.

"Soils," Lyon and Fippin, pp. 69–79.
"The Soil," Hall, pp. 32–56.
"Physical Properties of Soil," Warington, pp. 5–23.
"The Soil," King, p. 70.
"Soils," Hilgard, pp. 88–106.

PRACTICE ·XXXIV

DETERMINATION OF THE EFFECT OF CULTIVATION AND MULCHES UPON TEMPERATURE AND MOISTURE CONTENT

A number of students may work at this experiment, each one being assigned a definite problem.

Select a level area of 4 or 5 square rods and remove any vegetable matter, such as weeds, etc. Break up with plow or spade all but 1 square rod. Place a mulch of straw or leaves several inches deep upon half a square rod of both the plowed and the unplowed area. Roll a portion of the plowed area.

Determine temperature at 1, 2, and 4 inches in depth in each, on days when the sun is shining. Read the thermometer every 2 hours.

Determine moisture to a depth of 40 inches once each week for at least 4 weeks.

REFERENCES.
"Soils," Lyon and Fippin, p. 461.
"The Soil," Hall, pp. 120–123.
"Physical Properties of Soil," Warington, pp. 156–161.
"The Soil," King, pp. 230–234.
"Soils," Hilgard, pp. 304–305.

EFFECT OF SOLUBLE SALTS ON RETENTION OF CAPILLARY WATER

Use the stock soils, loose and compact, in the same tubes as in Practices XX, XXI, and XXII.

Make separate determinations for each solution, but run loose and compact soil at the same time.

Use distilled water and the following solutions: one-half normal [1] sodium chloride (NaCl), normal and three times normal solutions, and one-half normal and three times normal solutions of the following mixture of salts : sodium chloride (NaCl), sodium carbonate (Na_2CO_3), sodium nitrate ($NaNO_3$), sodium sulfate (Na_2SO_4), potassium nitrate (KNO_3), and potassium chloride (KCl). If desirable other salts may be added or substituted for any of these.

Determine the percentage of water retained and the acre inches, as in the preceding practices.

Explain your results.

REFERENCES.
"Physical Properties of Soil," Warington, pp. 211–231.
"Principles and Practice of Agricultural Analysis," Wiley, Vol. I, p. 170.

[1] By a normal solution is understood one which contains one " gram-equivalent " of the active reagent dissolved in one liter of solution. By "gram-equivalent" is meant the amount of substance corresponding to one gram-atom (1.01 g.) of hydrogen ("Analytical Chemistry," Treadwell and Hall, Vol. II, p. 423). A normal solution of sodium chloride then is one in which one liter of solution contains the number of grams of NaCl represented by its molecular weight, or 58.5 g. of NaCl (Na $= 23.05 + $ Cl $= 35.45$).

A twice normal solution contains twice as much NaCl, or 117.0 g. per liter of solution.

A normal solution of sodium carbonate (Na_2CO_3) contains the number of grams per liter of solution represented by one half of the molecular weight, as there are two hydrogen equivalents in the molecule of Na_2CO_3.

Na_2CO_3 ($Na_2 = 46.1 + $ C $= 12 + O_3 = 48$) $= 106.1$; then 53.05 g. of Na_2CO_3 per liter is a normal solution.

A one-half normal solution of NaCl is equivalent to 29,250 parts per million, or 2.925 per cent of the solution is NaCl; a normal solution of NaCl, 58,500 parts per million, or 5.85 per cent. A one-half normal solution of Na_2CO_3 is equivalent to 26,525 parts per million, or 2.65 per cent; a normal solution of Na_2CO_3, 53,050 parts per million, or 5.305 per cent.

PRACTICE XXXVI

DETERMINATION OF COEFFICIENT OF EVAPORATION

Fill six evaporimeters [1] with the same soil to within 1 inch of the top. Compact all uniformly.

Fill all tubes to the top as desired, or as follows:

No. 1, check (filled to top with the same kind of soil).

No. 2, 1 inch of sand.

No. 3, 1 inch of peat.

No. 4, 1 inch of sawdust or cut straw.

No. 5, 1 inch of gravel.

No. 6, pan of same area filled with water.

The tubes should be $6\frac{3}{4}$ inches in diameter so as to have an area of exactly 36 square inches, $\frac{1}{4}$ of a square foot, or $\frac{1}{174240}$ of an acre.

The base should be filled with water through the tube, and the water allowed to come up by capillarity through the soil.

Refill the base and place a cork or rubber stopper in the tube to avoid loss of water by evaporation.

Weigh the evaporimeter and record its weight. Weigh at 24-hour intervals for 1 week.

It is absolutely essential that all evaporimeters have the same exposure to heat and air currents. It may be well to conduct this practice in a greenhouse or in the open air early in the first or late in the second semester.

Find the coefficient of evaporation, the loss in pounds per acre during a period of 24 hours.

Compute the amount of evaporation in tons of water per acre and in acre inches per week. Tabulate results.

REFERENCES.

" Soils," Lyon and Fippin, pp. 195–215.

" The Soil," Hall, pp. 89–119.

" Physical Properties of Soil," Warington, pp. 107–118.

" Soils," Hilgard, pp. 254–262.

" Principles and Practice of Agricultural Analysis," Wiley, Vol. I, pp. 160–162.

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[1] An evaporimeter similar to that described by Wiley in his "Principles and Practice of Agricultural Analysis," Vol. I, p. 160, has been in use here for more than ten years. It is better to have a perforated bottom in the tube, whose sides extend to and stand on the bottom of the base. It will be necessary to have holes in the sides of the tube below the perforated bottom to admit water to the soil.